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FOREIGN TECHNOLOGY DIVISION

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by

Kazimierz Dabrowski

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SYSTEMS FOR COMBATTING AIRCRAFT ICING

Kazimierz Dąbrowski, Mgr. Inż.

The place of occurrance of aircraft icing and its effects. Methods used for ice removal, and to prevent its formation; defects and advantages of appliances in use. Examples of icing signalling devices.

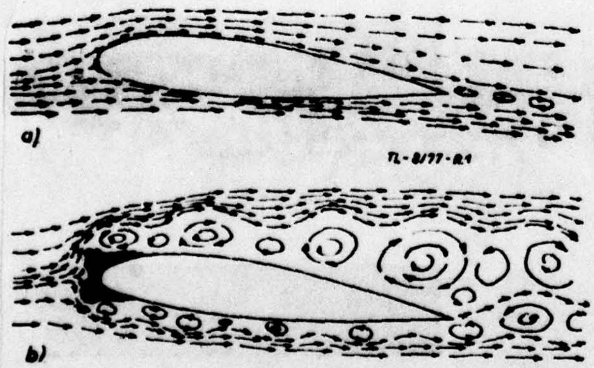
The phenomenon known as icing which results from water particles collecting from humid air and freezing on objects located in an air stream, has been long known. But only with the invention and development of aviation has it become a problem. This occurred when aircraft passed from the stage of <u>flying when it is possible</u> to <u>flying when it becomes necessary</u>, i.e., the stage of regular transport of people, mail, commodities, and military cargoes at any time of the day or night. Icing occurs most frequently in the autumn-winter-spring, however occasionally even in summer.

Ice attacks only certain places on the aircraft. These are therefore the sensitive areas: the attack edge of the wings and tail, the propeller blades, air intakes of any kind, frontal casings, and Pitot tubes. Depending on meteorological conditions, the speed of flight, the place on the aircraft, and the shape, the form, structure, and tempo of ice increase varies as does the degree of danger it presents. Sometimes the harmful influence is restricted to a change in the form of the wing-nose profile, causing, however, a decrease in the angle of incidence.

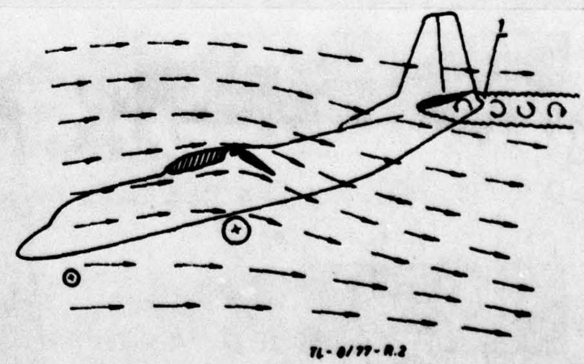
In the worst eventuality, heavy ice deposits produce both an increase in aircraft weight and a decline in lift, and increase in drag (Drawing 1), a decrease in engine power, and also a decline in efficiency and strong propeller vibration. The effect is such that a fully-fuelled aircraft cannot

maintain itself in level flight. If icing also occurs on the static- and total-pressure apertures, depriving the crew of indications by speedometer and altimeter, the situation becomes extremely dangerous.

Recently, an especial danger is the icing of the horizontal stabilizer. The effect on landing flaps currently used produces a strong downward deviation in the stabilizer. This is especially so when the stabilizer is not located very high. Thus, the stabilizer functions at a very negative angle of incidence. Even an insignificant amount of ice on the attack edge causes separation of flows on the stabilizer's base, and the violent decrease of its aerodynamic lift directed downward. Equilibrium is maintained -- the aircraft GOES INTO A DIVE and the pilot can do nothing with the controls. If this phenomenon occurs at the final landing phase, at the moment of full flaps, only immediate return of the flaps to their previous position can save the aircraft from destruction (Drawing 2). Locating the horizontal stabilizer high (the control surfaces having the form of the letter T) decreases this risk to a marked degree.



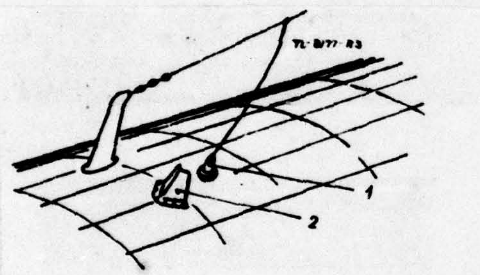
Drawing 1: Flow around the wing profile: a) a clear wing; b) an iced wing.



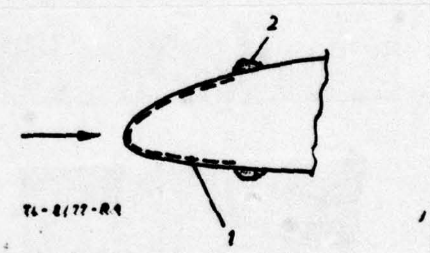
Drawing 2: Effects of icing on the horizontal stabilizer, 1) left stream zone.

Before we discuss methods for ice removal and protecting against its build-up, it is necessary to mention the passive anti-icing efforts, such as any kind of protective shields against ice accumulation on sensitive elements. Those are seen first of all in the introduction of antennae shielded by the fuselage (Drawing 3), and also occasionally at the exit points of pushers controlling the ailerons and balancing flaps.

Two types of appliances to combat ice on aircraft can be distinguished. There are de-icing appliances, that is, for removing already-formed ice, and anti-icing devices, that is, not permitting ice formation. The latter, of course, require more thermal energy, for they must also evaporate the water which might freeze on the unheated portions of the fuselage, forming so-called barrier ice (Drawing 4).



Drawing 3: Shield for the aerial fairlead: 1) insulator; 2) anti-icing shield.



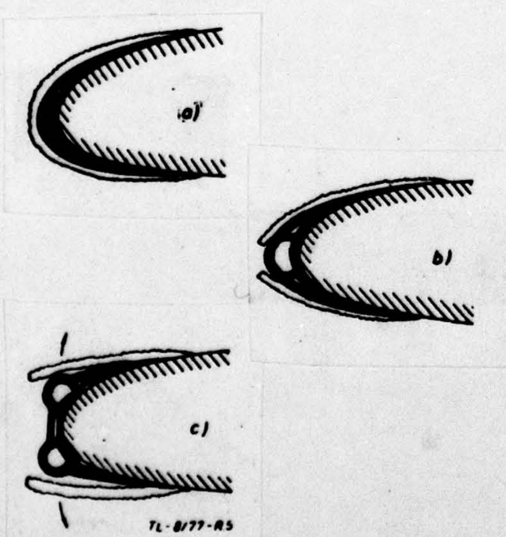
Drawing 4: Barrier ice on a wing: 1) heated area; 2) barrier ice

On the wings and control surfaces, the necessity of using anti-icing devices doesn't arise. It is necessary only to heat air intakes to the turbine engine as well as the wing portions adjacent to the fuselage if the engines are located to the rear of the fuselage, as currently occurs often (especially on passenger aircraft). In the last case, ice chunks may not be

allowed to fall from the wings, as they would impair the engines. In the other cases, de-icing type devices will suffice, though in conditions of severe icing the system must operate at intervals: after allowing a certain thickness of ice to form (not so thick as to interfere with air flow); the device engages and the ice drops off, and is blown away by the air stream.

The simplest apparent solution is heating adequately the elements exposed to icing. However, the amount of energy required for this is rather considerable. Any additional source of energy on an aircraft unfortunately amounts to an increase in its weight, or to a limitation of its carrying capacity.

Initially the easiest and cheapest to realize is the use of mechanical crushing of the ice on the attack edge of the wings and control surfaces. This system (the so-called GOODRICH system) requires the installation of rubber tubes along the deiced edges. The tubes in a normal flight are flat and conform to the outline of the profile. In order to remove ice, compressed air is introduced into the tubes, which causes them to inflate -- cracking the ice. (Drawing 5)



Drawing 5: Action of a mechanical de-icer:

a) start,

b) breaking the ice, and

c) shedding the ice.

This system can be used on the wings as well as on the stabilizers. There is also used a system with rubber chambers aligned one next to the other along chords (in the form of ribs), which has the advantage of the least effect on the profile's form. Deformation of the profile is the great drawback of the system. Another fault is its ineffectiveness in the case of engaging the apparatus too late, when the ice thickness has been able to increase considerably. However, in spite of the development of thermal methods, mechanical de-icing is still used today on many aircraft, even recently built ones.

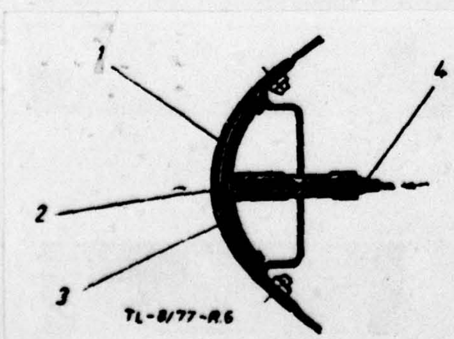
Chemical de-icing has also been long known. It is true that anti-icing pastes applied before a flight to the wings has not found broad application, but anti-icing liquids used to prevent icing and remove ice accumulations have long been used both on land and in the air. This means has its chief use for the propellers and windshields of the crew cabin. The fluids used are generally various alcohol mixtures.

Chemical de-icing has been largely replaced by thermal methods. However, aircraft have appeared recently on which fluids to de-ice propellers and stabilizers are used. This system (the so-called TKS system) requires squeezing the de-icing fluid through porous covers on the attack edges. Such covers are produced from dense steel grid, in which separate wires are heated. A pump forces the liquid through a filter under several atmospheres of pressure. The expenditure of liquid is limited by a porous layer PCW, located under a porous steel cover (Drawing 6). The unit is engaged periodically; when a certain ice thickness has accumulated, the fluid is discharged between the ice and the cover, causing the ice to fall off.

This system is also characterized by light weight and small energy requirements. Thus, it can be especially useful on small aircraft. It does not create the risk of freezing of already-fused ice, which is a defect in all thermal systems. Obviously, its defect is that it limits the time and range of a flight in icing circumstances (like all other liquid systems). There are also technical difficulties in using the TKS system on curvilinear attacking edges. Finally, one must consider the necessity of special protection of the covers from corrosive action by the de-icing liquid.

The thermal methods can be regarded as the basic means of combatting ice on aircraft. The competing systems are: heating by hot air; and, electrical heating.

The ingenious idea of utilizing the heat of the engines' exhaust gases is, in practical application, difficult. Sending the exhaust of a piston engine directly into the canals in the wing nose is not possible, due to its pollution and corrosive effects, as well as the possibility of overheating the structure. Thus, the necessity arises of using suitable heaters or heat exchangers built into the exhaust system of the engine, preheating fresh air brought from outside. In this case, however, only a part of the heat energy of the exhaust is usable.



Drawing 6: The TKS de-icing system: 1) porous nose cover, 2) micro-porous insert, 3) space to be filled with fluid, and 4) duct for introducing the fluid.

It also will not suffice simply to conduct hot air to the wing, because the heat would be provided from it only at the nose cover, while the air travelling through the canal would scarcely deliver any heat. With this dual loss, the heat furnished to the cover is insufficient to raise its temperature significantly. Thus, it is necessary to force all the hot air to flow along the nose cover by special channels arranged, for example, through a corrugated internal cover. The channel system can even be dual (as in Drawing 7). A system of so-called microejectors is also possible. Here hot air is sent through a series of nozzles (ejectors) from which it goes into channels running through the cover simultaneously carrying off a portion of the colder air. From the channels the cooled air returns to a general duct and once again a portion of it is taken into circulation and mixed with new portions of hot air (Drawing 8).

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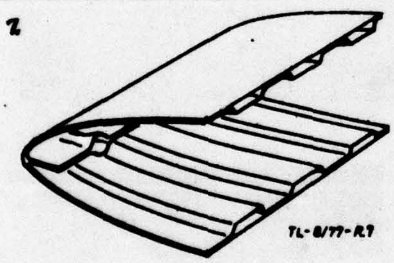

Drawing 7: Channels in the wing nose for de-icing by hot air.

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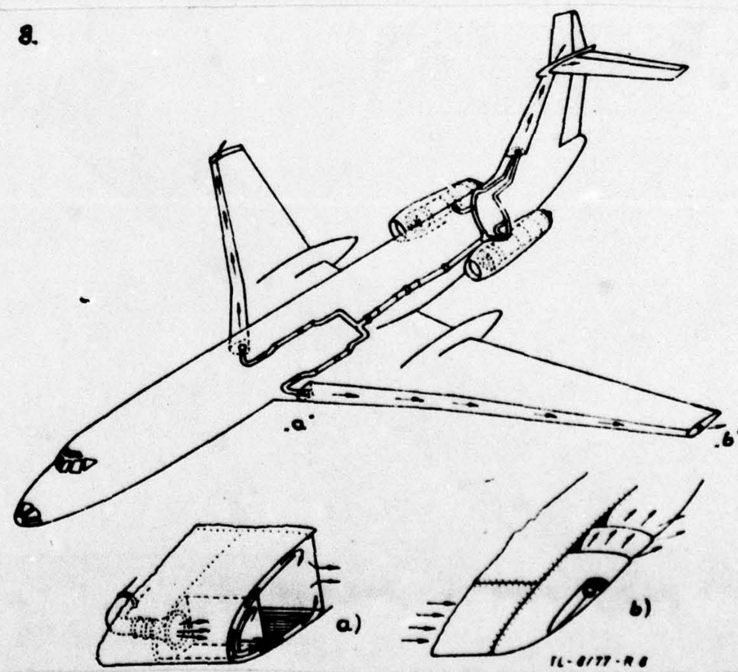


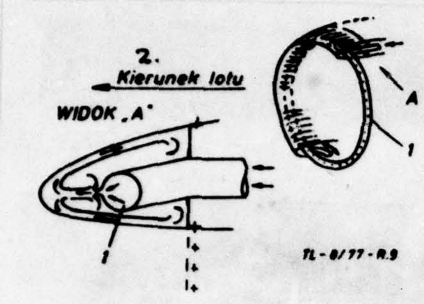
Drawing 8: De-icing system in the wings of a TU-134 aircraft: a) detail of channels in the wing nose; b) used air outlet.

With the introduction of turbine engines, the problem of awkward and heavy heat exchangers was removed, thanks to the possibility of using the clean hot air, under considerable pressure, from the engine's compressor. But here also too much of this air cannot be used, for it is also needed for heating, ventilation, and to produce pressurized cabins; and draining air from the compressor causes certain losses in engine power (in the case of turbo prop engines -- on the order of 2% power loss from taking 1% of the air flowing through the engine).

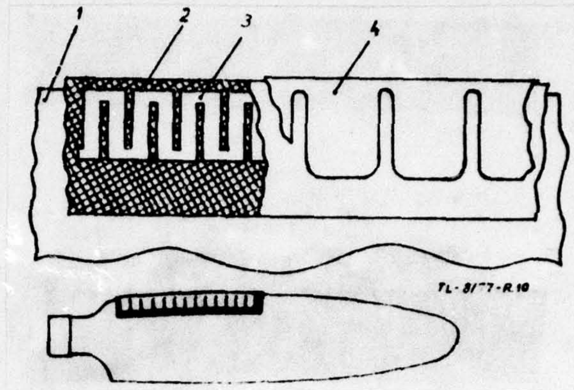
Electrical heating -- much simpler structurally -- requires a powerful energy source on the aircraft, which, of course, is costly. In several instances, however, it is irreplaceable, e.g., to de-ice small elements like Pitot tubes, static pressure openings, and others. Sometimes (as in the IL-18 aircraft) electrical de-icing includes the entire aircraft: wings, tail, propellers, windows. More often, however, electrical heating is used to de-ice the smaller elements.

Wing and tail heaters are often attached from the inside to the nose covers. Electrical insulation can be made by layers of glass laminate. Individual sections of the heaters are, in general, switched on in a predetermined sequence. Besides this along the attack edge is a heater supplied without interruption; the so-called blade heater. Its task is to cut the ice on the nose into two shells -- upper and lower, which periodically fall away (Drawing 9). Heating elements for the propeller blades are most often attached by a layer of rubber. The rubber cover can be protected from damage from sand and stones by an attached thin steel sheet (Drawing 10). As a heating element for the crews cabin windows, a thin transparent conductive film is used, located between two glass windows.

Often a layer of gold is used here. This is, of course, quite costly. In Drawing 11 is shown the heated pilot's window in the TU-134 aircraft.



Drawing 9: Intake heating of a jet engine: 1) microejector tube; 2) flight direction.

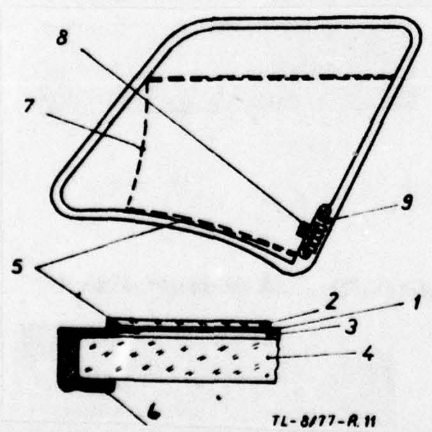


Drawing 10: Heater cover on a propeller blade: 1) blade attack edge; 2) insulating layer; 3) heating element; 4) protective cover of steel foil.

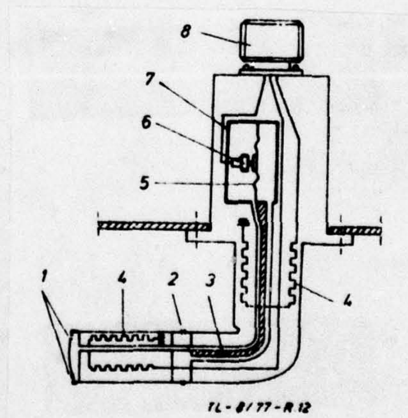
Finally, it is necessary to discuss apparatus enabling the crew to orient itself during an icing threat. The simplest signal of icing is a rod located on a short stanchion behind the window in the pilot's line of sight. According to the amount of ice appearing on the bar, the pilot can judge the intensity of the icing. The bar can be electrically heated in order to grade the ice, and prepare for further work. The current state of icing of parts of the aircraft is important information for the pilot. A suitable arrangement of windows and special reflectors should enable the crew to see the wing's attack edges and tail at night.

On larger aircraft, automatic icing signalling devices are now used. One of these systems -- used to signal turbine engine icing - works on the basis of the speedometer (Drawing 12). A

tube placed in the stream of air of the engine intake has, on the front, total pressure openings, and on the side, static pressure openings. When there is no icing, the difference between total and static pressure, corresponding to the speed of the flow, is transferred to a chamber with a membrane which, in the obtuse position, is in contact with the electric contacts of the signalling device. Even a small amount of ice on the tube will clog the total pressure openings, and in a moment the pressure on both sides of the membrane is equalized by a calibrated vent. The membrane is released, and closes the contacts which engage a signal light in the crew's cabin. Simultaneously the indicator engages electric heating. The ice melts, uncovering the openings and the indicator is ready to function anew. The signalling system can be used for automatically engaging the engine intakes. The disadvantage of such an indicator is its sensitivity to fouling of the openings -- which can cause false alarms.



Drawing 11: Electrically heated pilot's window: 1) conducting layer; 2) outer pane; 3) adhesive layer; 4) inner pane; 5) energy supply; 6) window frame; 7) edge of heating layer; 8) temperature sensors (thermistors); and 9) electric terminals.

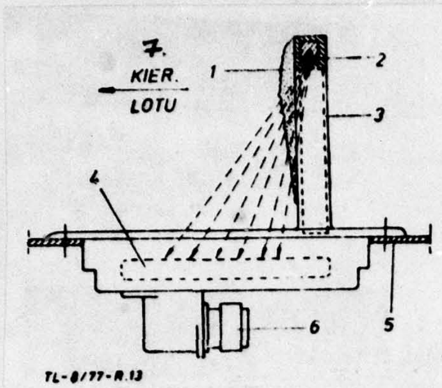


Drawing 12: Engine icing indicator: 1) total pressure openings; 2) static pressure openings; 3) calibrated opening; 4) electric heaters; 5) membrane; 6) electric contact; 7) manometric chamber; and 8) electrical connection.

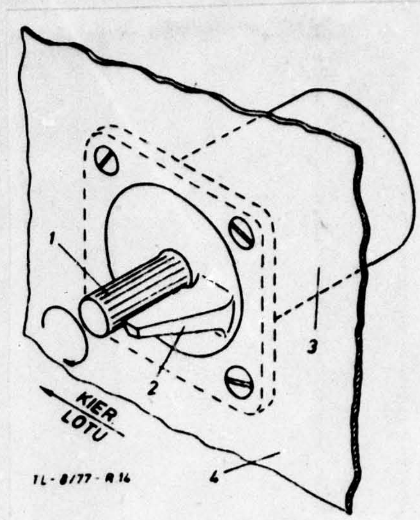
Another example is the radioactive indicator for icing -- used on i.a., the TU-134 and AN-24 aircraft (Drawing 13). Inside a short bar and set perpendicularly to the fuselage cover, is a source of radioactive radiation, the rays of which are directed frontwards towards the housing of the instrument in the fuselage. A radiated beam strikes a particle counter within the instrument. During icing, the number of of particles striking the counter is limited by ice on the bar, which causes an appropriate signal regarding icing to be sent. Simultaneously, a heater is automatically engaged, which melts the accumulated ice. As long as the icing conditions last, the ice periodically forms on the indicator bar, engaging the signal.

The indicator systems mentioned above are not the only ones. A great many useful systems are known, each with its advantages and disadvantages. One of the most widely used is the electromechanical indicator (Drawing 14). An electric motor turns a grooved shaft projected outside the fuselage skin. During icing, ice collects on this shaft. Alongside the shaft is an immobile blade, which scrapes away the ice layers from the shaft as it turns. The motor stator is also placed in the housing, and is maintained in a fixed position by a spring system. Increasing the turning moment by cutting through ice causes the motor stator to attempt to turn in the direction opposite to the rotor. The springs give slightly, and the motor stator engages a midro-switch, engaging a signalling network.

However, it must not be concluded that any of these devices allows a pilot to disregard the meteorological conditions in which the flight is planned and performed. The pilot must be aware of how to avoid icing zones, in every possible manner. A flight downward -- towards higher temperatures -- does not always improve the situation.



Drawing 13: Radioactive indicator: 1) ice; 2) source of radioactive radiation; 3) heater; 4) particle counter; 5) fusilage cover; 6) electrical connection; and 7) direction of flight.



Drawing 14: Electromechanical indicator: 1) shaft; 2) stationary blade; 3) instrument housing; and 4) fusilage skin.

Of course, these skills are necessary above all to pilots of aircraft not having any deicing apparatus. But also on aircraft designed for flights in icing conditions, it can happen that the equipment available turns out to be insufficient. Also, one must always consider the possibility of partial or total loss of function of the devices for combatting icing; e.g., by stopping one engine the main source of electrical energy is impaired, or even by blowing a fuse or relay in the system controlling the deicing system. Then the successful completion of the flight might rely solely on the pilot and his meteorological knowledge.

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